Durability of New Roads: Case Study of the Algerian East West Highway

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***Abstract*— The goal of this paper is to analysis the damages sustained by the new Algerian highway called AutoRoute east-west. Many sections of this new infrastructure are closed or partially opened after two years of exploitation. The main damages are in relation with the structure layers of the road and with the deformation of the side of embankment in the sloped sites. This linear network must have a length of seven thousand kilometers and realization duration of ten years. The road section situated in Algeria has one thousand and two hundred kilometers and itsstudy has start in 1997. In September 2012, the Minister of pavement declares that the final cost is twelve milliards in us dollar (12 billion us $).The study begins by the description and the analysis of the damages sustained by this structure and it finish by the identification of the causes who have generated these faults.**

***Index Terms*—Durability, Algerian highway, damages, identification, causes**

I. Introduction

This big road symbolizes the territorial unification of the North African Region called "Maghreb" and the economic integration between these countries. This linear network must have a length of seven thousand kilometers and realization duration of ten years. The road section situated in Algeria has one thousand and two hundred kilometres and the study of section located in Algeria starts in 1997. The real beginning of work starts in 2007 and must finish at first January 2011. In January 2011, the project is finish in a proportion of 95% and some little amenities around a few towns must be finished. The costs of works are estimated at three, then five and at end seven milliards us dollars and it is considered by the Algerian Minister of pavement like project of century [1]. In September 2013, the Minister of pavement declares that the final cost is twelve milliards us dollar (12 billion us $).

The sustainable development of any Society is linked to the system composed by the following elements: human Society, Economy, Transport and Environment. So, to satisfy its economic development, every society needs to develop the transport network, but the construction of roads and railways uses land and generates negative effects on the Environment and Ecology.

Durability of road is one of the most important factors in maintaining a high level of safety for road users and low cost engineering. This fact improvements the quality of the structures and create a compatible action with the environment and the sustainable development.

A. Presentation of Project.

The Algerian section is part of the 7,000 km of the North African AutoRoute, which is being developed in two stages: East and West. The figure 1 shows the path of the Algerian section of the highway. The road section situated in Algeria has one thousand and two hundred kilometers and the study of section located in Algeria starts in 1997 and the beginning of work starts in 2007 and must finish at first January 2011.The first phase, the East-West Highway, involves the construction of a 1,216 km section linking Annaba in the east to Tlemcen in the west, passing through 24 Algerian provinces. The first section is further divided into three sub-sections: the Eastern section, Central section and Western section. The development will have 12 tunnels, 70 viaducts, 60 interchanges and 390 structures. It also includes a provision for building truck stops, service stations and maintenance facilities.

Figure 1. Path of the actual Algerian section of the Highway

Manuscript received November 30, 2017; revised February 5, 2018.

doi: 10.18178/ijscer.7.1.87-91

The highway passes through many regions with different geography. Indeed, the west border of Algeria is classed as zone with weak precipitations, the centre is classed as zone with middle precipitations, and the East is considered as humid zone. The corps of pavement was designed with a uniform structure. The Fig. 1 shows the Path of the actual Algerian section of the Highway.

B. Pavement Type

Road pavements come in a multitude of configurations and variations. The present road can be categorized according to the main building materials used in the pavement:

- Sub-base: broken stone (40 cm thickness),
- Road-base: gravel (30 cm thickness),
- Surface layer: bituminous mixture (6cm thickness).

The Fig. 2 shows the different structures of the layers that compose the highway.

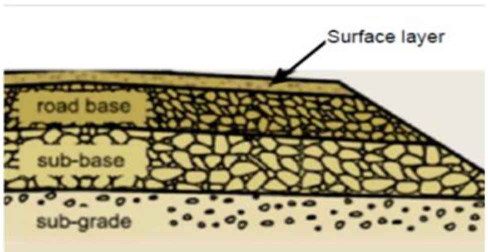

Figure 2. Structure of road pavement

C. Construction.

The "Autoroute Transmaghrébine" over the entire 1,200km stretch is designed as follows: a base course of cement treated gravelly sand is placed to a thickness of 20cm, followed by a 14cm bituminous bound base, with the road finally being surfaced with a wearing course of asphaltic concrete (0/14) between 6 and 8cm thick. The 1,200km stretch of the highway will use a base course of cement-treated gravelly sand, laid 20cm thick. Following a 14cm bituminous bound base, the road will be coated with 6-8cm of asphaltic concrete. Of the three project sections, the Eastern section is the largest. Costing $5bn, it will include 43 bridges on the main route and three tunnels. Around 110 million cubic meters of earth will be moved and about 1.93 million cubic meters of concrete used during construction. The East-West Highway project was launched by Algerian President in March 2007.

II. Characterization of Damages

Cracks on subgrades and pavement were the most common phenomenon of rainfall damage. Severely damaged sections of the highway had many transversal and longitudinal cracks, which occurred on the shoulders and pavement with a width up to 5-15 cm. They extended the entire width of the embankment and cut off the subgrade and pavement with a width up to 30-100 cm.

A. Identification of Damages

The present analysis is limited to the road; the damages sustained by some tunnels are not related.

Many sections of this new infrastructure are closed or partially opened after two years of exploitation. The main damages are in relation with the structure layers of the road and with the deformation of the side of embankment in the sloped sites.

The photos 3 to 8 show the damages sustained by the pavement and the embankments of the road under action of the rainfall.

The Fig. 3 shows the damages generate by flooding on the road because of absence of rainwater drainage.

The Fig. 4 shows the longitudinal fissure caused by a lack bearing of structure of road by fatigue phenomenon.

The Fig. 5 shows the collapse of road caused by settlement of soil.

The Fig. 6 illustrates the Settlement of bank caused by landslide.

The Fig. 7 illustrates the Collapse caused by a geological variation in the soil and water infiltration; and Fig. 8 shows the Settlement of soil caused by water infiltration and water saturation of soil (bad drainage).

Figure 3. Flooding of road caused by absence of rainwater drainage

Figure 4. Longitudinal fissure caused by a lack bearing of structure of road by fatigue phenomenon

Figure 5. Collapse of road caused by settlement of soil

Figure 6. Settlement of bank caused by landslide

Figure 7. Collapse caused by a geological variation in the soil and water infiltration

Figure 8. Settlement of soil caused by water infiltration and water saturation of soil (bad drainage)

B. Interpretation of Damage Causes

The exposed damages can be explained by the assumptions that will follow.

1) Insufficient Compaction

The purpose of compaction is to increase the quality of road building materials such as soils, gravel and aggregate. The effect of compaction is to reduce the volume of air in the material. By forcing the soil particles closer together, the density is increased and the soil becomes stronger. This enables the materials to carry heavier loads and increases their resistance to erosion. A dense material also absorbs less water and thereby improves the performance of the material. Equally, a densely compacted material resists any further decreases in its volume when exposed to heavy traffic loads [2]. Soils in their natural state consist of solid particles, water and air. Air does not contribute to the strength and stability of the soil - on the contrary, it reduces the stability of a soil. A certain optimum quantity of water, usually between 8 to 20%, depending on the soil type, provides a lubricating effect between the soil particles and thereby facilitates the compaction. Having a certain amount of water in the soils during compaction has a significant effect in terms of achieving the required pavement strength and stability [3].Clayey soils have the ability to contain more water than granular soils, and the optimal moisture content is higher in clays than in sands and gravels [4]. The water lubricates the particles and allows them to settle in a dense mass. If the soil contains too much moisture and is too wet, the soil particles are kept apart by the water. When the soil is too moist and attempts are made to compact it, it will not compress, but flow out sideways when pressure is applied [5].

2) Clay soil in the site of landslide

Clay has plastic properties, which means it has very specific characteristics depending on its moisture content. The effect of compacting clayey soils is very much dependent on the amount of moisture in the soil. When dry, the clay is hard and firm and in the context of road building actually provides a strong and firm basis on which a road can be constructed. However, when applying compaction, the clay needs to contain a certain level of moisture in order to achieve the desired effect. Dry clay loses its cohesion and thereby compromises the result of compaction. The soil will simply crumble and turn to dust. Due to its impermeable features, dry clay is difficult to mix with water. When water is added, it is often necessary to wait for a while for the water to soak into the material. By watering at the end of the day, the soils can be left to soak overnight. Alternatively, it is possible to turn the materials with a disc plough in order to facilitate the mixing of water into the materials. The characteristics of clay change radically when adding water [6]. Clays should be compacted close to its optimum water content.

3) Water saturation of soil and Settlement

The main advantage of compaction of soils used in embankments and fills is that it reduces settlement caused by consolidation of the soil within the body of the embankment. Through proper compaction, it is possible to limit later consolidation and settlement of the soils in a fill.

Although future settlements may not be entirely eradicated, the compaction may produce a uniform density of the soils and reduce this process to a minimum [7]. Also it may result in future settlements being more uniform and thereby limit the damage caused by it. The figure shows the graphs of dry density of different soils according to the moisture saturation.

4) Instability of slope along the road

The deformation of the base of the slope is generated by the undrained soil and by the non-adequate angle of the bank. The reinforcement of slope again landslide can to be realized by many artifices such as concrete walls, gabions walls, nails, anchors, etc. These recommendations are known in the engineering literature [8]. Indeed, every solution must be chosen in relation with the environment and the costs [9].

III. Discussion

The relationships between pavement, soil and water are complex. The durability of roadways has many direct and indirect impacts on the cost and on the global national development. To complete this study, it is recommended to achieve the expertise by a deep analysis about the thickness of pavement structures, the drainage of the roadway, the optimal compaction and the evacuation of water of rainfall along the longitudinal axis.

Some observations can be made on the deficiency of geotechnical studies and the control of the execution of the works. Good compaction is not difficult to achieve, however, it requires a good understanding of what is actually taking place when applying compaction to soils and surfacing materials. Good knowledge of the properties and performance of the materials, combined with the correct use of available equipment should result in reaching the prescribed quality levels. The effect of compaction varies depending on the nature of the soil. The behavior of clayey materials is different of sandy or gravel materials [10]. The thickness of bituminous layer is not sufficient and is not waterproof [11], [12].

The final cost is twelve milliard of us dollar (12 billion us $) for 1200 km. The international ratio is between 6 to 8 million dollars per kilometer for a Highway having three (3) lanes [13], [14]. This difference in the costs is origin of a large national debate [15].

IV. Conclusion

The analysis of damages can to give some conclusions and recommendations. The durability of any structures or works is linked with the quality of the Design, the Materials, the Realization, the Monitoring and the Nature of Environment. Indeed, the geotechnique study of soil and the knowledge of the rainfall action on the soil and material are required for any infrastructure. The most important deductions are: Insufficient Compaction, Clay soil in the site of landslide, Water saturation of soil, Settlement and Instability of slope along the road.

The correlation between durability, costs, and amortization investment must be fixed early, for any plan of structure.

The main remark concerning this project is its cost and the quality of the works realization. This critical report on the quality of works and the extra cost (additional cost) can be explicated by the non-maturation of the design and by the weak monitoring of execution of tasks. According to the recommendations of the Algerian department of public works and transport, the maintenance of a new road begins after seven years of service. In this case study, the damages sustained by the road have been observed immediately after one to two years after reception of many sections of highway.

For future infrastructures, it is recommended to take in account the nature of soil, material, drainage and good compaction. These parameters influence the durability of road and can to disturb the good working of the traffic.

It is very regrettable that until this day, any impact study is not launched on the probable or real consequences generated by the realization of this Mega project on the Environment.

In conclusion, one can to say that the objective of this expertise: identification and interpretation of causes of damages sustained by a new highway is achieved.

Acknowledgment

The authors thank the Colleagues of the national Agency of Highway for its collaboration and the Laboratory of Water, Environment, Geomecanique, and Works (LEEGO) and the Laboratory of Built in Environment (LBE) for their support.

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